Urinary System: Renal Physiology for Medical Students

Chapter 28: Urine Concentration and Dilution;
Regulation of Extracellular Fluid Osmolarity
and Sodium Concentration

Reference: Guyton & Hall, Jordanian first edition

Part I

Dr. Ebaa M. Alzayadneh, PhD.

Email: e.zayadneh@ju.edu.jo

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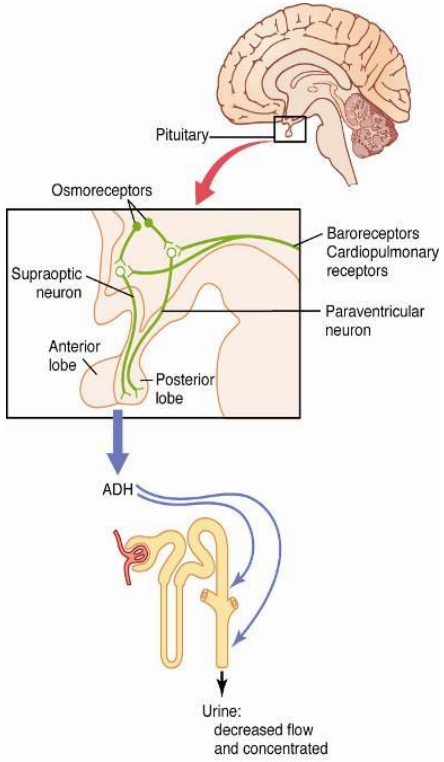
Objectives

- Identify the mechanisms by which the kidney can dilute or concentrate urine
- Understand the concept of Obligatory Urine Volume
- Understand the mechanism of countercurrent multiplier in the loop of Henle and countercurrent exchanger in vasa recta.
- Understand the concept of “Free” Water Clearance.
- Identify the role for urea to the concentrating ability of the kidney.
- Understand the role of ADH and thirst center in kidney function and fluid homeostasis.

Control of Extracellular Osmolarity (NaCl Concentration)



- ADH
- Thirst

→ ADH -Thirst Osmoreceptor System

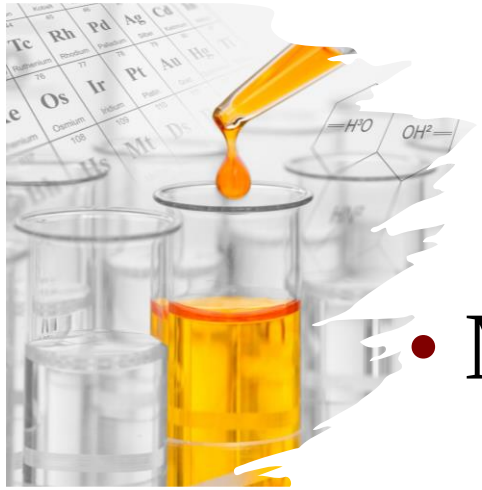
Mechanism:

increased extracellular osmolarity (NaCl)

stimulates ADH release, which increases

H_2O reabsorption, and stimulates thirst (intake of water)

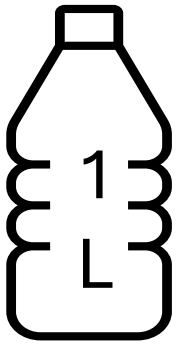
Concentration and Dilution of the Urine

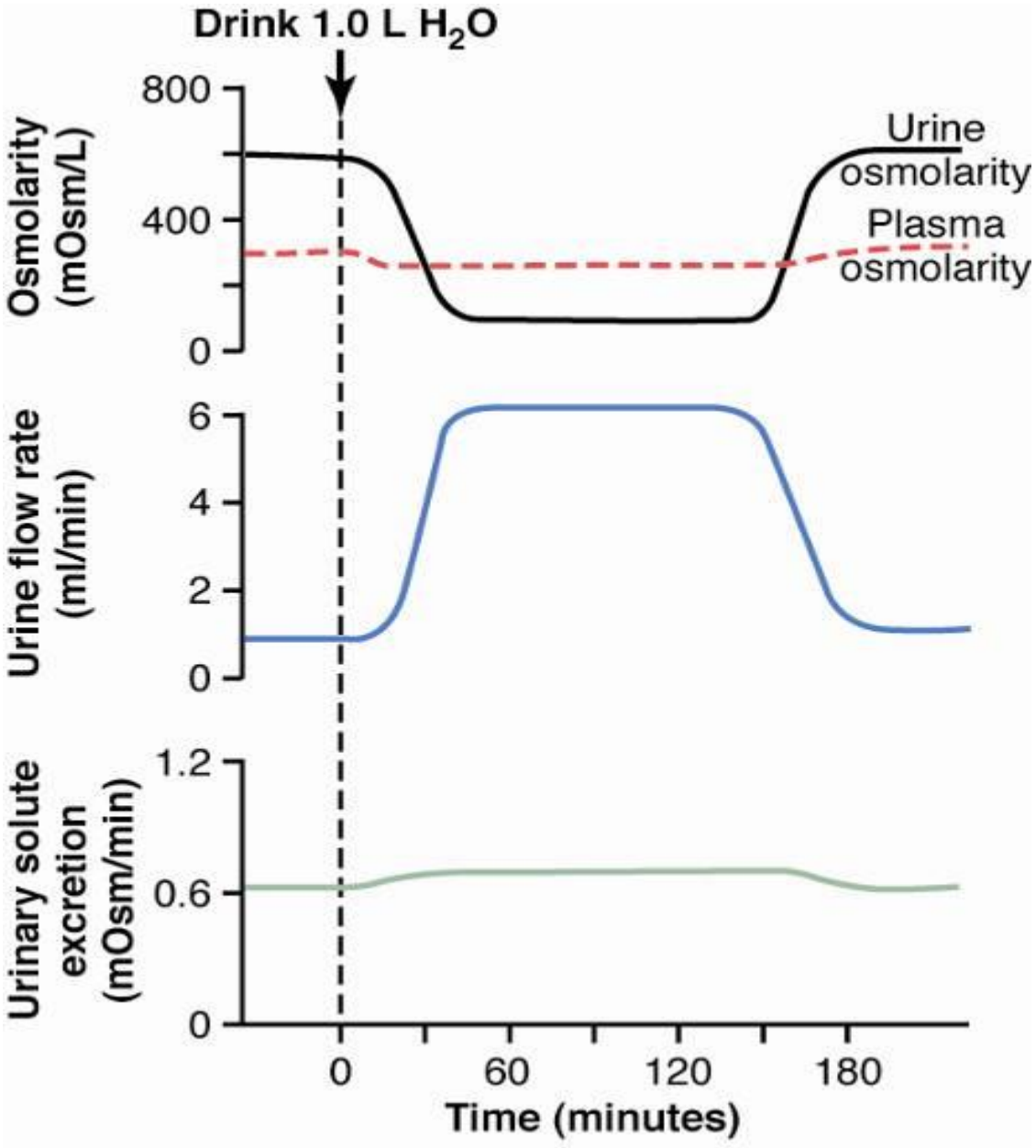


- Maximal urine concentration
  = 1200 - 1400 mOsm / L
  (specific gravity ~ 1.030)

- Minimal urine concentration
  = 50 - 70 mOsm / L
  (specific gravity ~ 1.003)

Water diuresis in a human after ingestion of 1 liter of water.





Formation of a dilute urine

- Continue electrolyte reabsorption
- Decrease water reabsorption

Mechanism:

Decreased ADH release and reduced water permeability in distal and collecting tubules

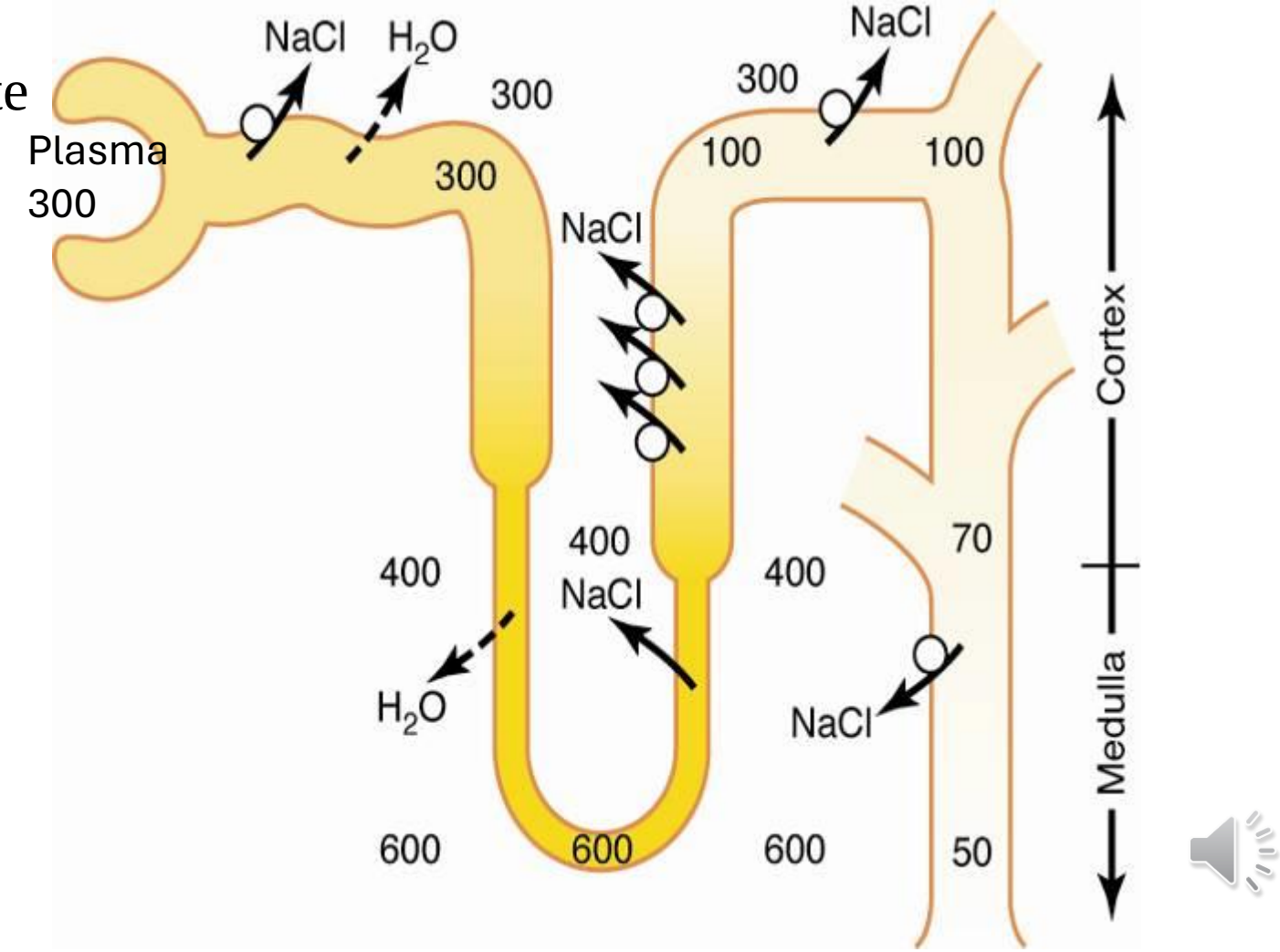


Figure 28-2

Relationship between urine osmolarity and specific gravity

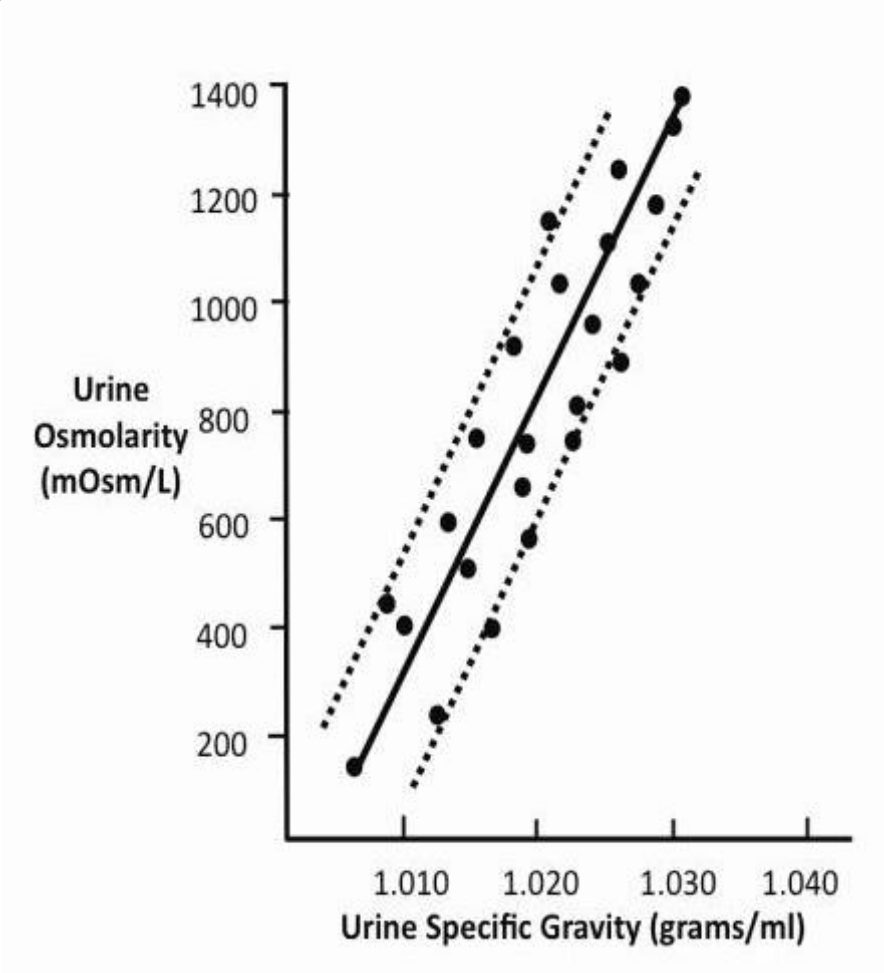


Figure 28-3

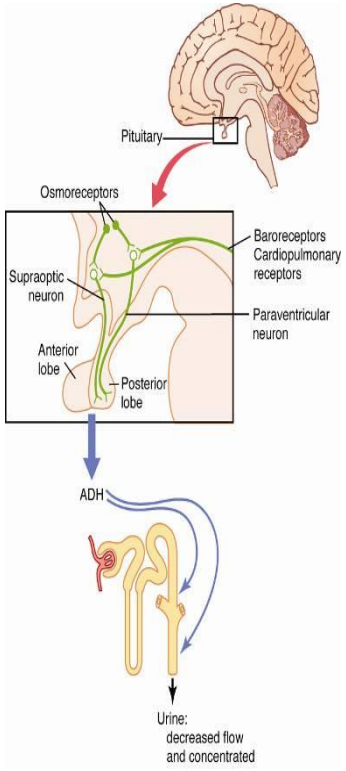
- rising by .001 for every 35 to 40 mosmol/kg increase in osmolality.
- 280 mosmol/kg (which is isosmotic to plasma) has a specific gravity of 1.008 or 1.009.

Influenced by

- glucose in urine
- protein in urine
- antibiotics
- radiocontrast media

specific gravity reach 1.030 to 1.050 (falsely suggesting a very concentrated urine), despite a urine osmolality that may be only 300 mosmol/kg.

Formation of a Concentrated Urine



- Continue electrolyte reabsorption
- Increase water reabsorption

Mechanism :

- Increased ADH release which increases water permeability in distal and collecting tubules
- High osmolarity of renal medulla
- Countercurrent flow of tubular fluid

Formation of a Concentrated Urine when antidiuretic hormone (ADH) are high.

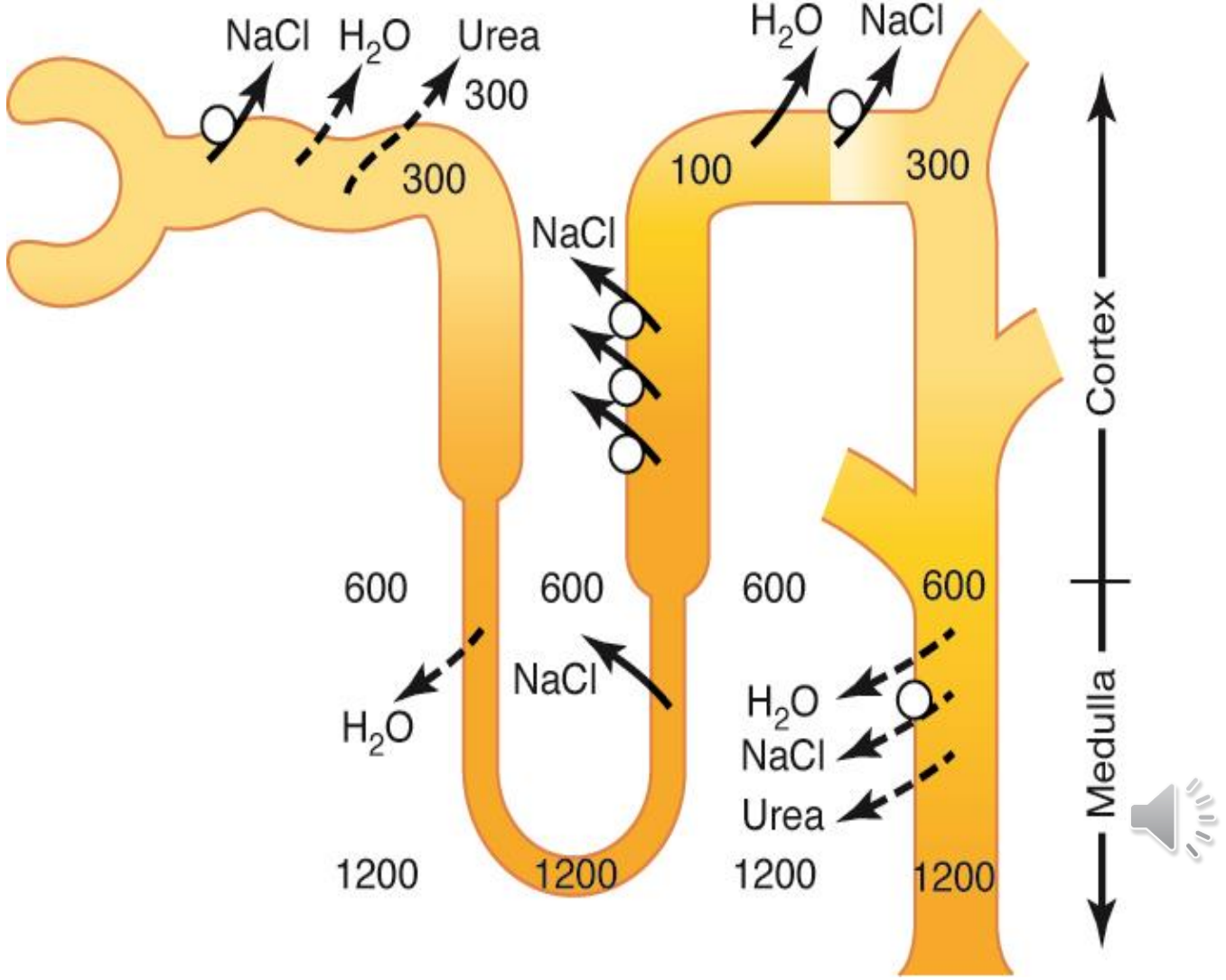


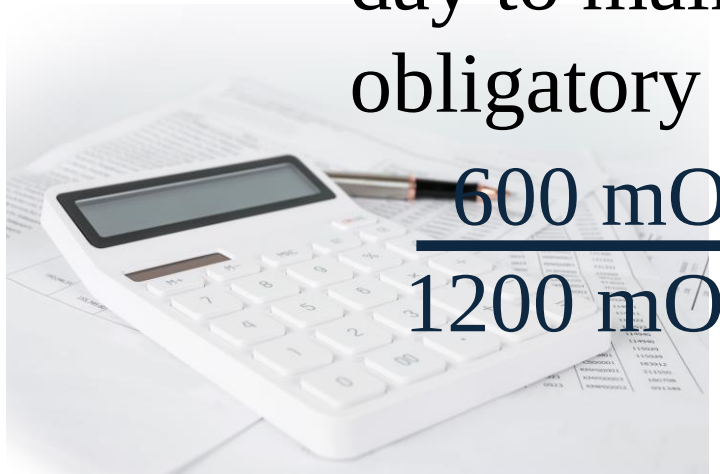
Figure 28-4

Obligatory Urine Volume

The minimum urine volume in which the excreted solute can be dissolved and excreted

Example:

If the max. urine osmolarity is 1200 mOsm/L, and 600 mOsm of solute must be excreted each day to maintain electrolyte balance, the obligatory urine volume is:



$$\frac{600\ \text{mOsm/d}}{1200\ \text{mOsm/L}} = 0.5\ \text{L/day, 20 ml/hr}$$

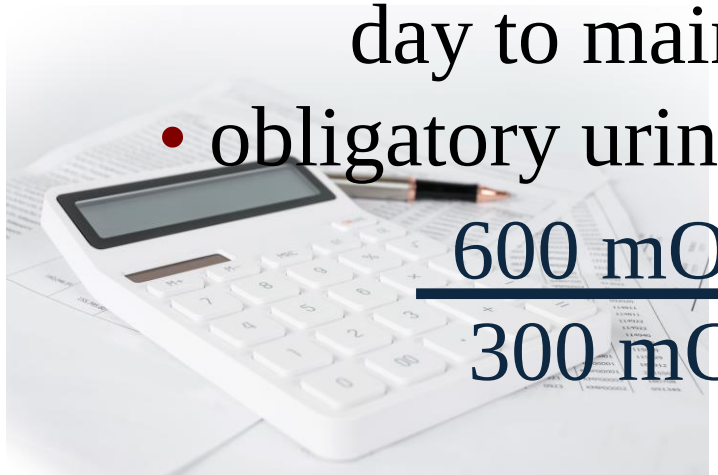
If less Oligurea

Obligatory Urine Volume

In renal disease the obligatory urine volume may be increased due to impaired urine concentrating ability

Example:

- If the max. urine osmolarity = 300 mOsm/L,
- If 600 mOsm of solute must be excreted each day to maintain electrolyte balance
- obligatory urine volume = ?



$$\frac{600\ \text{mOsm/d}}{300\ \text{mOsm/L}} = 2.0\ \text{L/day}$$

Factors That Contribute to Buildup of Solute in Renal Medulla - Countercurrent Multiplier

- Active transport of Na^+, Cl^-, K^+ and other ions from thick ascending loop of Henle into medullary interstitium
- Active transport of ions from medullary collecting ducts into interstitium
- Passive diffusion of urea from medullary collecting ducts into interstitium
- Diffusion of only small amounts of water into medullary interstitium

Countercurrent multiplier system in the loop of Henle.

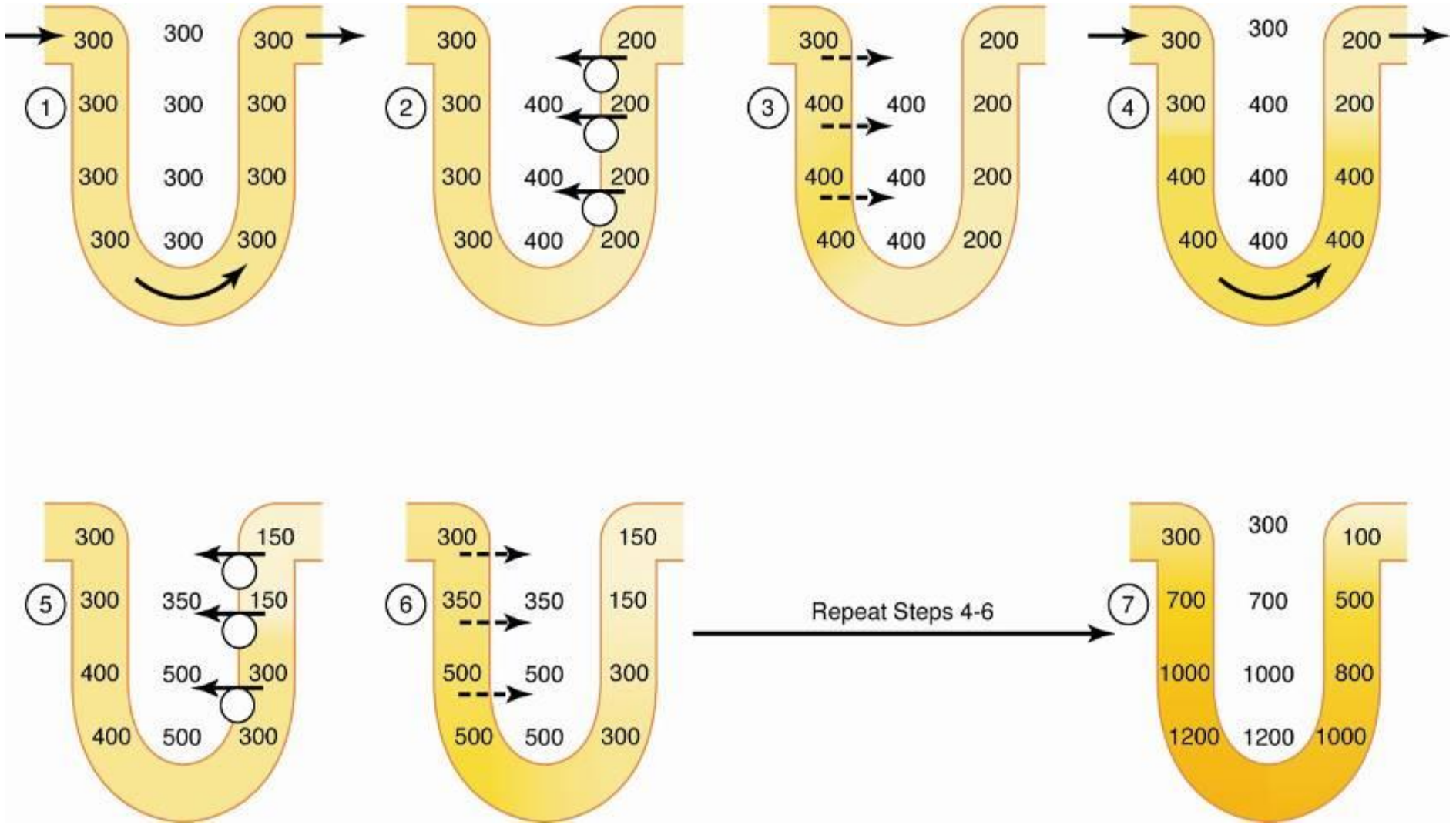


Figure 28-4

Net Effects of Countercurrent Multiplier

1. More solute than water is added to the renal medulla.
   i.e solutes are “trapped” in the renal medulla
2. Fluid in the ascending loop is diluted
3. Most of the water reabsorption occurs in the cortex
   (i.e. in the proximal tubule and in the distal convoluted tubule) rather than in the medulla
4. Horizontal gradient of solute concentration established by the active pumping of NaCl is “multiplied” by countercurrent flow of fluid.

Summary of Tubule Characteristics

Tubule Segment	Active NaCl Transport	Permeability		
		H_2O	NaCl	Urea
Proximal	++	+++	+	+
Thin Desc.	0	+++	+	+
Thin Ascen.	0	0	+	+
Thick Ascen.	+++	0	0	0
Distal	+	+ADH	0	0
Cortical Coll.	+	+ADH	0	0
Inner Medullary Coll.	+	+ADH	0	+++

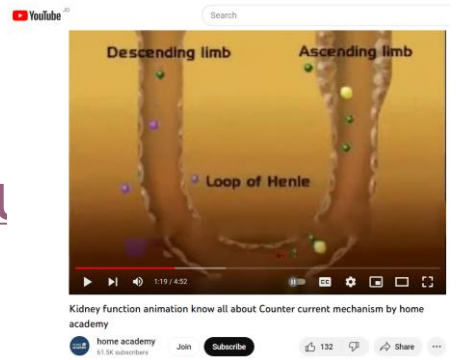
Audio-visual Aid

Please check this animation out demonstrating

Countercurrent multiplier

Kidney function animation know all abou Counter

current mechanism by home academy – YouTube



and counter current exchanger:

Countercurrent Mechanism v3 - YouTube